

S P E C I F I C A T I O N

TITLE

"SOUND RECORDING AND REPRODUCTION SYSTEM"

RELATED APPLICATION DATA

5 This application is a continuation-in-part of U.S. Patent application Serial No. 08/289,257, filed on August 11, 1994. ^{now abandoned}

BACKGROUND OF THE INVENTION

10 The present invention generally relates to a modular device, system and method for storing, playing back and recording audio data. More specifically, the present invention relates to a modular device, system and method for reproducing audio data, such as voice and sound effects in a realistic manner.

15 It is, of course, generally known to generate simulated sounds in response to external stimuli, such as motion. One common industry in which sound production is often simulated is the model railroad industry. Sounds, such as those made by various animals, such as cows, sheep, pigs, and the like, are often reproduced. These sounds are typically generated in connection with a particular car of a railroad to enhance the interest and realism of the model railroad.

25 Another example of sounds being generated in conjunction with model trains is the heightened realism attained when used with a steam or diesel locomotive. In the past, when sound features have been controlled in conjunction with a model locomotive, methods other than motion have been used to turn these types of sound effects on and off. Some of these methods have been: DC voltage superimposed upon an AC voltage, magnets, reed switches, ^{or} Hall effect sensors ~~or motion~~. The use of radio signals or a carrier control signal superimposed upon an

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AC or DC voltage have been used as well. Furthermore, a separate controller, which varies either AC or DC voltage or current, was required to control the speed and direction of the model train. There has not been a means to integrate all simulated controllable functions a model train may have into a model locomotive or car.

A need, therefore, exists to realistically reproduce and control sound effects, control model train motors and special effects. This need can be best filled by using a sound unit and Digital Command Control for controlling simulated sounds and simultaneously control propulsion of the model trains. Digital Command Control is a type of control that makes use of a digital bi-polar signal to control model trains. As defined in the NMRA Standards, the National Model Railroad Association baseline, Digital Command Control signal consists of a stream of transitions between two equal voltage levels that have opposite polarity. Alternate transitions are ~~separated from one bit to the next~~ ^a. The remaining transitions divide each bit into a first part and last part. Use of this format gives the hobbyist the most choices for controlling aspects of a sound unit mounted in a model train as a self contained unit or in a track side structure as a accessory.

An example of a known sound effect producing model railroad car is described in U.S. Patent No. 5,267,318 to Severson et al. The '318 patent teaches a speech synthesis circuit for playing selected cow voices stored as digital data in an EPROM. In a random mode of operation, a state generator provides a pseudo-random count that is used to select among four different ~~each~~ cow voices, one of which is silence. The resulting audio output is perceived as random contented cow sounds. A

pendulum motion detector provides an indication of lateral motion of the system. An up/down motion counter maintains a motion count reflecting the level of excitation of the system and the cows. The motion counter increments responsive to motion and decrements gradually in the absence of detected motion. A motion count of at least four invokes a triggered mode of operation in which the counter output is used to select among four different excited cow voices.

In the alternate embodiment of the present invention that uses only the sound reproduction apparatus, its improvement over the '318 patent is that no motion counter, micro-controller or state generator is needed to generate a response to a lateral movement of the sound car. The simple movement of the car is all that is needed to cause a response from the sound memory to play-back simple sound effects.

Previous inventions that have tried to control sound effects for model locomotives have only utilized an electro-mechanical means to control the synchronized sound functions whereas the present invention controls all aspects using digital control of the following: sound, model locomotive speed, direction and special effects on board. Another known system that relates to model trains is U.S. Patent No. 5,174,216 to *Miller et al.* In the '216 patent, there is no means to execute sound effects at the model train enthusiast's discretion or to control speed, direction or other onboard special effects. The '216 patent also utilizes a single chuff sample for all speeds, that is controlled using an opto-sensor to define an on or off state. The opto-sensor simply controls one chuff sound effect no matter at what speed the model locomotive may be traveling. The speed

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There have been attempts at controlling the speed of a model locomotive, sound and special effects to overcome the above deficiencies. One known system that attempted to do this is taught in U.S. Patent No. 4,914,431. In this patent, the motor controller device is used with AC-powered model trains where typically these types of trains make use of variable AC voltage to control the speed of a locomotive, typically described as "Lionel trains." Furthermore, these types of trains make use of a three-position switch that is controlled by a solenoid to determine forward, neutral or reverse. This unit is called a reverse unit, which the '431 patent is designed to operate exclusively. The scope of the '431 patent is intended to sync the electronic reverse units of a master and slave locomotive. Furthermore, the control system uses state generators for expansion of the remote control effects found on a model locomotive. This is accomplished by simply using a positive and or negative DC digital pulse repeatedly applied to create and to control a plurality of state control signals. Although each motor controller can operate up to sixteen states, only four state generators are enabled for use. This pulse signal is superimposed on the AC motor control supply voltage and can only control one set of special effects per usage. Another deficiency of the '431 patent is that, in its preferred embodiment, only two addresses are possible: a master and a slave. The '431 patent is not designed for multiple locomotives in use in multiple combinations. For the operator of DC powered trains, these deficiencies make the device unsuitable. Finally,

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motor controller are limited to: direction and deceleration only, and no provisions for additional features to be actuated remotely, such as operation of a sound unit or special lighting effects.

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As seen by the above patents, prior art exists; however, each makes use of a proprietary format that only operates each manufacturer's or inventor's devices and are limited in operational characteristics. The present invention, on the contrary, operates across any manufacturer's control systems as long they observe the NMRA digital format now in practice.

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The present invention overcomes the above shortcomings by utilizing a micro-controller that decodes a discreet bi-polar digital command directed to its specific address for control of: sound effects, speed regulation, direction of a model locomotive and control ^{of} ~~other~~ on-board special effects. In addition, the constant voltage supplied to the track is able to supply a constant voltage ^{to} ~~to~~ ^{from} a regulated power source to the present invention at all times, no matter what the speed of the model locomotive. In addition to the simple features as outlined, the hobbyist also has access to certain registers that may be used to customize a model locomotive's motor control ^{characteristics} ~~characteristic~~ and sound features.

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The previously mentioned micro-controller uses, in this embodiment, a prescribed packet format that includes speed, direction and accessory/special effects commands. The preferred digital format that is used is dictated by the National Model Railroad Association. By using this format the present invention is able to inter-operate with control systems that are currently on the market and

a is not dependent on a proprietary control system. However, various digital formats exist for the use of model train control, and the present invention can be adapted to these as well. All aspects of the present invention may be controlled in a "hands-off" manner by executing various addressed commands that are sent on a plurality of tracks as a digital signal to a specific model locomotive. The only limit on this type of invention is the size of the micro-controller and sound memory.

SUMMARY OF THE INVENTION

The present invention can be executed in two configurations, the first uses only the sound reproduction apparatus. The other configuration uses the sound reproduction apparatus and a digital control decoder which is useful when used with model trains that use Digital Command Control.

In the first embodiment, the sound storage and reproduction section of the present invention is used to generate a sound with or without external stimuli, such as being used in a sound-producing, model railroad car. Moreover, the present embodiment provides a system and a method for recording audio data and playing back the audio data in an asynchronous manner. This embodiment provides a simplified means to store and play-back the audio from the sound storage chip. In the preferred embodiment of the present invention an EEPROM is used, that uses Direct Analog Storage Technology (DAST™ by Information Storage Devices) which makes an analog recording of the audio information.

In an alternate embodiment of the sound storage section, the audio is digitized and compressed, and voice synthesis is used as steps in recording the information

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but not limited to
onto a digital EPROM for use with, for example, a Yamaha
YM3812 as a sound generator. For play-back, a digital to
analog conversion is necessary to convert the digitized
information into an analog wave form. The preferred
embodiment of the present invention uses an analog EEPROM
that does not require any of these intermediate steps. So
the present device simplifies the recording and playback
operation for this type of application when used in the
preferred embodiment.

Furthermore, by the addition of a microphone to the
preferred embodiment, the consumer may add his own voice
to the pre-recorded material to tailor the sound effect
in some applications through the use of the DAST™ EEPROM
that permits recording and re-recording of additional
voice or audio effects. This additional voice information
may be blocked from overwriting the pre-recorded material
on the chip through the use of the multiple address
capabilities the DAST™ EEPROM possesses.

When the device is executed in the second
configuration using Digital Command Control, the
following functions may be accessed and controlled:
sound, speed, acceleration, deceleration, direction and
any special effects. In a preferred embodiment, a
plurality of sound effects are stored on a sound storage
device at predetermined addresses that employ DAST™
technology to store an analog sound effect. These same
sound effects and principles may also be utilized using
a digital type of sound storage chip and a Yamaha YM3812
sound generator. *as an example*

An addressed Digital Command Control signal is
amplified prior to being placed on the rails to a
suitable amplitude to power the sound unit's analog *or digital*
sample memory, integral decoder, power the model loco-

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change the speed and direction of the model locomotive based upon information contained within the decoded digital packets. The speed resolution may be expressed as a number of steps which a model locomotive takes to achieve maximum speed from a full stop. A preferred embodiment uses a digital format prescribed by the National Model Railroad Association which ^{currently} allows for three different speed resolutions: 14, 28, and 128 speed steps. The greater the number of speed steps in a given resolution, the more precise the motor control will be. The motor control aspects of the sound decoder may act directly upon a properly decoded digital packet and then translate the information contained within the packet into an appropriate speed and direction. Alternately, several registers of the serial EEPROM that the micro-controller can access known as "Control Variables" may be used to modify the information contained within the decoded digital packet prior to the translation into an appropriate speed, direction or for motor noise snubbing for the purpose of motor control. These registers may be fixed in firmware or programmable by the hobbyist. Some examples of these Control Variables, but not limited to, can include acceleration, deceleration, start voltages, motor response curves and motor noise snubbing. These Control Variables allow an end user to tailor a model locomotive's motor operation characteristics to personal preferences, often enhancing the operation of the device.

Certain Control Variables are also reserved for use by the sound aspects of the device. These Control Variables may be fixed in firmware or alternatively programmable by the hobbyist. These Control Variables allow an end user to tailor a model locomotives's sound aspects to personal preferences often enhancing the

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5 operation of the device. By utilizing this particular feature, momentum effects may be replicated using steam or diesel sound effects. ^{In addition, may be} ~~or~~ the volume ^{from} adjusted remotely ~~from~~ the hand controller. In addition to the sound and motor control aspects, special effects may be controlled. These may be, but are not limited to, lights, different flasher beacons and smoke effects. Each of the sound unit aspects that may be controlled by the model train enthusiast are addressed by specific groups of digital packets for specific sound units. In other words, any of the sounds or types of movement which a real locomotive make are now possible in the model world. The previously mentioned sounds and control of the model locomotive's propulsion may be executed in combinations or in a prescribed method of preference. ⁰³

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The first step in creating the sound effects for the present invention is to record the actual sounds of the animals, sound effects, steam or diesel locomotives. These sounds are mastered and edited for use in either configuration of the present invention. The sound effects that are used in the asynchronous sound module are then simply recorded onto the chip for recall using the enabling means of the Hall effect sensor or other types of sensors. In the Digital Command Control Configuration, the recording of the sound effects is accomplished by recording all necessary sound effects from a specific type of the actual locomotive, whether diesel or steam. When a specific diesel locomotive's sound characteristics are recorded and paired to a matching model, the distinct sound characteristics are carried over to the model setting, giving a unique sound to each locomotive. However, steam locomotives vary in driver wheel arrangements and physical size. These two things

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In another embodiment of the present invention, a model railroad car system is provided including a plurality of cars, at least one of the plurality of cars capable of producing simulated sounds. The system has a power source providing power to the plurality of cars and means for producing sound connected to the power source. The means for producing sound is capable of recording and playing back sounds. An asynchronous activation means is constructed and arranged to provide an enable signal to the means for producing sound resulting in playing back one of the sounds.

15 In an embodiment, the activation means of the model
railroad car system is a magnetically responsive sensor
constructed and arranged near a magnetic field wherein
the magnetic field may be altered by a magnet.

In an embodiment, the method further has the steps of providing a magnetic source; creating a magnetic field; and providing a magnetic responsive sensing means responsive to changes in the magnetic field to thereby generate the signal.

Another application for the alternate embodiment is a sound reproducing device wherein a microphone may be connected to a consumer device for the home, such as a doorbell or audio-type message pad.

It is, therefore, an advantage of the present invention to create a modular sound recall and play back circuit to adapt to a variety of applications for producing sound.

Still further, an advantage of the present invention is to provide a system and a method to internally activate audio in the first embodiment without the need

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to externally trigger the at least one sound.

And, another advantage of the present invention is to provide a system and a method to trigger or activate the sound module using the same circuit design.

5 Another advantage of the present invention is it will decode multiple broadcasted digital packets of which one will match the sound units preset address.

10 Another advantage of the present invention is that it may see one match for the sound unit's preset address and may activate an appropriate sound, light or other special effect or institute changes upon motor speed or direction based upon the information contained within the digitally addressed and decoded broadcasted packets.

15 Another advantage is that each model train operator has independent control of the following functions of their particular sound unit: all sound functions, model train motor control, and on-board special effects.

20 A further advantage is the sound effects may be synchronous using the speed packets to determine a speed sound effect or asynchronous if a bell, whistle/horn or background sound effect is activated for the decoded digital packet.

25 Another advantage of the present invention is the use of multiple sound samples to emulate the change in speed and work load.

Another advantage is automatic modes of control for specific sound effects.

30 Another advantage of the present invention is any of the sound unit's decoder functions, i.e. sound, motor control or special effects functions, may be acted upon by the decoder at any random location around the model train setting and are not limited to predetermined locations.

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FIG. 1 illustrates a side view of a model railroad car embodying the components required for reproducing sounds with the principles of the first embodiment of the

present invention.

FIG. 2 illustrates a top plan view of an embodiment of the components mounted on a circuit board creating a base of a model railroad car, the components embodying the principles of the present invention for reproducing simulated sounds.

FIG. 3 illustrates a side view of an embodiment of a magnet supported by a pendulum over a sensor for the present invention.

FIG. 4 illustrates a block diagram of an embodiment of the components necessary for implementing the system and method of the present invention.

FIGS. 5A-5C illustrates a circuit diagram of an embodiment of a portion of the components for generating sounds in response to an enable signal for the system and the method of the present invention.

FIG. 6 illustrates a circuit diagram of an embodiment of recording circuitry for the present invention.

FIGS. 7A-7C illustrates in schematic diagram form of the components contained on the first of two printed circuit boards in the original configuration.

FIGS. 8A-8C illustrates, in schematic diagram form, the components contained on the second of two printed circuit boards in the original configuration.

FIGS. 9A-9C illustrates in, schematic diagram form, the components contained on the second of two printed circuit boards in an alternate configuration.

FIG. 10 illustrates a graphical representation of a Digital Command Control (DCC) baseline packet.

FIGS. 11-20 illustrate, in flow chart form, the operation of the micro-controller software.

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**DETAILED DESCRIPTION OF THE PRESENTLY
PREFERRED EMBODIMENTS**

Referring now to the drawings for an embodiment of the present invention, FIGS. 1 and 2 illustrate assembly views of a model railroad car encompassing one embodiment of the present invention. As illustrated in FIG. 1, an exemplary model train car 1 is shown. The model train car 1 includes a platform or base 10 operatively connected to a plurality of wheels 12 as is generally known. The base 10 includes a printed circuit (PC) board for connection of electrical components thereon. Although not illustrated, the electrical components hereinafter described are typically enclosed within a housing such that the model train car 1 encloses the components and provides a decorative appearance in its ordinary usage.

The base 10 includes a PC board for electrical connection of components thereon. One of these components is an analog sound storage processing chip 14 manufactured by, for example, Information Storage Devices (ISD). The processing chip 14 is provided with DAST™ analog memory for storage following recording of various sounds recorded thereon or for subsequent reproduction of the recorded sounds. Connected to the processing chip 14 is an audio amplifier 16 and a sensor 18, such as a Hall-effect sensor as illustrated in FIGS. 1 and 2 having a northern polarity. Of course, other sensors or activators may be implemented. The DAST™ analog storage chip 14 also includes an internal microphone amplifier 38 (FIG. 4) external to or built into the chip 14. The microphone 38 enables recording of additional desired sounds on the chip 14.

An integral part of the sensor 18 includes a non-conductive and non-magnetic pendulum 24 and a magnet 26

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Referring to FIG. 4, the power source 28 is
5 activated either on or off by the switch 30. When power
is provided to the system, the voltage regulator 32
limits the voltage to the analog processing chip 14 to
five volts. The sound module DAST™ analog processing
chip 14 is activated by the sensor 18 as previously
10 discussed. The sensor 18 may be a Hall-effect sensor 18.

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The first section is the power supply previously described. The power supply when used with a model railroad car may run off of track voltage wherein the power is input to a full-wave bridge rectifier and a capacitor acting as a filter. The output is then connected to a voltage regulator. The nine volt DC input from, for example, a nine volt DC battery, is tied in at a node through a diode. If a nine volt battery is used in conjunction with the track power, the battery acts as a low voltage backup keeping the module voltage up when the track voltage drops off or shuts off. Power is switched to the module via the SPST switch.

The third section of the circuit is the audio amplifier. In a preferred embodiment, the amplifier is

an LM386N-1. The output of the audio amplifier is capacitively coupled to a volume potentiometer. The wiper of the potentiometer is the input of the amplifier. The output of the amplifier is capacitively coupled and connected to a speaker.

The fourth section of the circuit is the message activation or chip enabling section of the circuit. Pin 23 of the sound effects chip is the chip enable. Chip enable is an active low signal, and the pin is pulled ^{high} up with a resistor and a decoupling capacitor in parallel. The configuration of the device initiates the message inside the chip to be played by pulling of the pin to ground. The message plays once unless the pin is held low. If held low, the message continues to repeat until the pin is allowed to get pulled to high.

The pin can be activated several ways as previously set forth. A Hall-effect sensor below a suspended magnet may be implemented in a preferred embodiment. When a train car travels along or is jarred on a track, the change in the magnetic field from the magnet swaying causes the Hall-effect sensor to activate and give a momentary pull to ground thereby initiating the chip. Therefore, the present invention is activated by inertia-sensitive control.

The fifth section of the present invention is the option of recording custom messages. The chip has a built-in microphone amplifier that can be used to record audio data. This is controlled by the state of the playback/record pin. When held low, the chip is then put into record mode and will record audio as long as the chip enable is held low. Alternatively, an external microphone may be implemented for recording on the chip.

Referring to FIG. 6, two microphone inputs to the

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ISD device, MIC (pin 17) and MIC REF (pin 18) are illustrated. The two pins are differential inputs to an on-chip microphone preamplifier. A non-biased microphone can be connected directly across the two inputs. A 470
5 kOhm resistor, connected parallel to a 4.7 MF capacitor is placed across the automatic gain control AGC input (pin 19). These two components set up the attack and release time constant for the internal AGC circuit inside the chip. The AGC circuit controls the gain of the
10 microphone preamplifier built inside the chip.

To record a new message on the chip, two pins on the chip are controlled, /Chip Enable and Playback/Record. /Chip Enable controls the start of both the record and
15 play cycles. The level of the Playback/Record pin will determine whether a new message is to be recorded or the saved message played back. Pin 27 (P/R) is normally held high and messages play back as long as chip enable (/CE pin 23) is held low. If P/R is pulled to ground and then /CE is pulled low, the chip is then automatically placed
20 into record mode and records the analog signals in real time picked up by the microphone. Recording stops when /CE is brought high. As previously mentioned, by controlling the address or logic level, the location of the new message can be controlled such that it will not
25 record over previous audio.

Due to the limited space available within model train locomotives and cars, the present configuration uses two narrow elongated printed circuit boards (PCB's) stacked upon each other on which the electronic
30 components are mounted in this embodiment. The circuit boards are electrically interconnected by means of a multi-pin plug on the upper PCB and a mating socket on the lower PCB.

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FIG. 7 illustrates in schematic form the components mounted on the upper PCB. The micro-controller, IC1 section 101 contains and executes the software program required for this invention. The present configuration of this invention uses a Part No. Z86E08-08PSC from Zilog, Inc., Campbell CA, ^{IC1 Section 101} The other components mounted on the upper PCB are the micro-controller oscillator ^{section}, 102, IC2 103, a Part No. 93C56A serial electrically erasable read only memory from National Semiconductor, Inc., Santa Clara, CA; the function #0 and #1 output transistors and connector section 106; the motor drive transistors and filter network section 107; the DCC digital input signal conditioning components section 108; the power supply section 109; the electrical plug to the lower PCB ^{section}, 110; a shift register ^{section}, 111; and a Hall effect sensor section 112.

FIGS. 8A-8C illustrates in schematic form the components mounted on the lower PCB in the present configuration. The direct analog storage, DASTTM, integrated circuit, IC5, and associated decoupling capacitors section 201. The present configuration of this invention uses a Part No. ISD1020A for IC5 from Information Storage Devices, Inc., San Jose, California. The other components mounted on the lower PCB are the mating socket to the upper PCB section 203; an audio compander circuit section 204; an audio amplifier circuit with volume control section 205; and a Power Down/Reset Circuit section 206.

Referring now to FIGS. 7A-7C, operation of the upper PCB of the present invention will be described. A bi-polar digital signal of sufficient voltage and current is attached to J2 section 109 and the jumpers on J4 section 108 and J5 section 108 are placed between pins 2 and 3 on each. In this configuration, the power source is also the

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opto-isolator provides a safety layer of isolation between the ~~present and external situations~~⁶⁶. The Schmitt trigger aspect protects from data errors due to low level digital noise. The digital signal exits the opto-isolator in an inverted state and enters a micro-controller (IC1) through the Input No. 2 line section 101.

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The micro-controller's speed is set by a Crystal (XTAL 1)^{section} 102 and an on board oscillator.

There are several output lines associated with the micro-controller section 101. Two of the lines, output 10 and output 9, are connected to the gates of driver MOSFET transistors, Q1 and Q2 section 106, which are open drain, active low auxiliary outputs; function No. 0 and function No. 1 (F0 and F1) section 106. The transistors have current limiting resistors R1 and R2 section 106 connected to the drain-source path, in series with the load. The current limiting resistors' values are selected according to the load(s). In a typical model railroading application, Q1 is connected to a flashing LED beacon or similar device and is controlled as F1. Q2 is connected to the locomotive headlight and is controlled as F0. The use of F0 as head lamp control is based upon the NMRA DCC standard; however the function outputs can be re-configured for different loads and control assignments.

Output lines 1-4 section 105 are connected to the gates of driver MOSFET transistors, Q3-Q6 arranged in an H-bridge configuration section 107 for pulse width modulated bi-directional control of a DC motor. A controllable filter network is connected across the DC motor for the modification of motor drive wave shapes for the suppression of undesirable audible noise section 107.

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an audio compander section 204. The expansion does two things: the audio is expanded and the signal is restored to its original dynamic range; and when the audio is expanded, low-level audio noise in the system is attenuated giving an improved signal-to-noise ratio.

The third section of the circuit is the audio amplifier. In a preferred embodiment, the amplifier is an LM386N (IC4) section 205. The output of the audio expander is capacitively coupled to a volume potentiometer. The wiper of the potentiometer is the input of the amplifier. The output of the amplifier is capacitively coupled and connected to a ^{potentiometer} ~~speaker~~.

The fourth section of the circuit is the sound effect activation or chip enabling section of the circuit. One pin of the DAST™ integrated circuit (IC5) section 201 is the chip enable. Chip enable (/ce) is an active low signal, and the pin is pulled ^{high} ~~up~~ with a resistor. Chip enable is connected with output line 11 on the micro-controller. Sound effect playback is initiated by loading the appropriate address bits into the shift register section 111 on the upper PCB and then bringing chip enable low. Typically, for playback of a single sound effect, /ce is brought high after sound effect playback begins. If playback of consecutive sound effects is desired, /ce is left low. At the end of each sound effect, a signal is generated on another pin of the DAST™ chip (IC5) called End of Message (/eom) (active low). /eom is connected to input line No. 3 of the micro-controller section 101 through socket J7 section 203 and J1 section 110. If it is desired to repeat a sound effect, either with spaced repetition or with seamless looping, /eom is monitored to mark the end of the current sound effect being played allowing the micro-

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controller to precisely control repetition or looping.

a PNP transistors Q3 and Q4, ^{section} 206 have their bases connected to A6 and A7, respectively, and their collectors are tied to ground. The open emitters of Q3 and Q4 are connected to a pin of the DAST™ chip (IC5) section 201 which is labeled Power Down, an active high input. Power Down is connected to a pull up resistor (R14) section 206 and a decoupling capacitor (C18) section 206. When A6 and A7 are both high, Power Down goes high and the DAST™ chip (IC5) is taken into a standby state and reset. This is useful if the DAST™ chip (IC5) should ever become errant in operation or if it is desirable to interrupt a sound effect being played before it has reached completion.

13B Now refer to Figs. ^{9B-9C} 9B and 9C in order to understand the operation of the lower PCB of the present invention in an alternate configuration.

Ins A8 A digital synthesizer integrated circuit IC6 in ~~area~~ section 301 is now used for the production of sound effects. The present invention uses a Part No. YM3812 sound generator from Yamaha Systems Technology; San Jose, CA for IC6. ^{section} Sound effects are created by alternately loading address and data information into lines D1-D8 on IC6 ^{section} 301. The alternating action is controlled by a flip-flop section 306. A digital to analog converter (DAC) section 304 is used to change the digital outputs of IC6 ^{section} 301 into varying voltages, which are the sounds. In the present invention, a Part No. YM3014 from Yamaha Systems Technology, San Jose, CA is used for the DAC. The output of the DAC feeds into a unity gain buffer section 305. The output of the buffer feeds into a low pass filter section 307 before reaching the volume control potentiometer R11 which is part of the audio

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amplifier circuit section 305. In the present configuration, the amplifier is an LM386N (IC4) section 305 from National Semiconductor, Inc., Santa Clara, CA. The wiper of the potentiometer is the input of the amplifier. The output of the amplifier is capacitively coupled and connected to a speaker.

Now a detailed explanation of the software operation will be given. Refer now, additionally, to FIGS. 11-20.

Beginning at <START> section 501, the micro-controller section 101 is initialized in section 502. The appropriate lines are configured as either input or output. Initial values are loaded into specified registers of the micro-controller section 101. One important value is the address which is loaded section 503 from the serial EEPROM section 103. The address determines which data transmissions are intended for the device to act upon. Input line No. 2 on the micro-controller section 101 then begins to receive transmitted data from the components in section 108. The present invention is configured to accept data transmissions based upon a digital protocol "Digital Command Control" DCC; a standard established and maintained by the National Model Railroad Association, Chattanooga, TN.

Refer now additionally to FIG. 10 to understand the form of the digital data transmissions. DCC data consists of ^{bi-polar} ~~bipolar~~ transmissions of square wave pulses each containing two equal parts: one positive and one negative. The width or duration of the pulse determines if it will be interpreted as a digital "0" bit or a digital "1" bit. A digital "1" bit in a DCC transmission has a nominal duration of 58 microseconds for each of its two ^{parts} ~~part~~, section 402. A digital "0" bit in a DCC transmission will have a nominal duration of 100

microseconds for each of its two parts, section 403. A complete DCC transmission can contain a varied number of bytes and is termed a packet. The one chosen for example here is a DCC baseline packet section 401. A baseline packet contains four separate components, which are the preamble section 404, the address byte section 406, the instruction data byte section 408, and the error byte section 410.

Refer alternately to FIGS. 10 and 11 wherein section, 504 of the software looks at the preamble part section 404 of the DCC transmission. It is distinguished as a minimum of 10 "1" bits followed by a "0" bit section 405. Once reception of the preamble is completed, the software will begin to receive the rest of the bytes in section 505. Next is the address byte section 406 which contains eight bits which can have a value of either "1" or "0" and is terminated by a digital "0" bit section 407. Next comes the instruction byte section 408 which also contains eight bits and is terminated by a "0" bit as well as section 409. The last byte in a baseline packet is the error byte section 410 which contains eight bits and is terminated by a "1" bit section 411. The "1" bit also signifies the termination of the packet.

Once a complete packet is received, the software then checks the validity of the data by performing an error check in section 506. The error check requires that the Exclusive-Or logical function be performed upon the address byte and the data byte. If the result of this operation matches the value of the error byte, the packet is valid. If the packet is rejected as invalid, the software loops back to section 504 to ^{await} ~~look for~~ the next preamble.

If the data is deemed valid, it is first checked in

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section 507 to see if this was a baseline idle packet. Idle packets are part of the DCC standard and are often used for time delays. If an idle packet is detected, the software loops back to section 504 to begin receiving the next preamble as no further action is required.

If the packet was found not to be an idle packet, several tests are performed to determine what action is to be taken based upon the data. In each case, a failed test causes a branch to the next test.

Beginning with test section 508, if it is determined, this data is intended for any and all devices receiving the data; or as termed by the DCC standard, a broadcast command. If it is, a branch is taken at section 515. At the completion of the branch, the software is at section 521 of FIG. 12. The broadcast command data is tested to see if an emergency stop command has been issued at section 522. If an emergency stop command is detected, the appropriate actions are taken to effect an emergency stop of the model train locomotive section 523. The software then branches at section 524 back to FIG. 11 at section 514 to begin receiving a new preamble. If the broadcast command is not an emergency stop command, it is then tested to see if the present invention should be reset at section 525, termed a decoder reset by the DCC standard. If a decoder reset command has been received, the decoder is reset in section 526. The software then branches at section 527 back to FIG. 11 at section 514 to begin receiving a new preamble. If the broadcast command is not a decoder reset command, then it may be a future command which may be handled in section 528 with the appropriate action being taken. The software then branches at section 529 back to FIG. 11 at section 514 to begin receiving a new

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preamble.

Referring now to FIG. 11 at section 509, if the received data is not a broadcast command, it tests to see if it is a utility instruction for the decoder or consists of an instruction for the grouping of model train locomotives. If it is, a branch is taken at section 516 to FIG. 13 at section 530. The data is tested in section 531 if a decoder instruction is intended. If it is, the specific decoder instruction is executed in Fig. 13 at section 532. The software is then branched at section 533 back to FIG. 11 at section 514 to begin receiving a new preamble. If the data is not a decoder instruction, it may be a consist instruction. If it is, several possible actions can be taken in Fig. 13 at section 535 to allow two or more model train locomotives to be grouped together and function in actual operation as one. Once the consist instruction has been completed, or if the data does not contain a consist instruction, a branch is taken at section 536 or section 537 back to FIG. 11 at section 514 to begin receiving a new preamble.

Now referring to FIG. 11 at section 510, if the received data is not a decoder or consist instruction, it is tested to see if it contains advanced operations information. If it does, a branch is taken at section 517 to FIG. 14 at section 538. In section 539, the address information contained within the received data is compared to the pre-programmed address of the present invention. If the addresses do not match, it would be known that the information was intended for some other device. The software then branches at section 540 back to FIG. 11 at section 514 to begin receiving a new preamble. If the addresses match, it is known that the information

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contained within the advanced operations packet is intended for this device. Advanced operations is the means by which the DCC transmits speed data and direction when 128 step speed resolution is in place. Speed resolution may be explained as the maximum speed divided by the number of speed steps. If a model train locomotive has a maximum scale speed of 64 MPH and 128 step speed resolution is in place, each speed step is equal to a $\frac{1}{2}$ MPH increment. This is considered fine resolution. The speed and direction information is extracted from the data in sections 541 and 542, respectively. There are several sound effects to cover the operational speed range of a model train locomotive, whether steam or diesel type. This allows the sounds generated to closely correlate with the speed at which a model train locomotive is traveling for realistic operation. ~~There are not~~ however, ⁴¹⁰ sufficient sound effects to provide for a 1-to-1 ratio between speed steps and sound effects. The end user is then able to program certain configuration variable memory registers defined by the manufacturer and contained within the serial EEPROM FIGS. ^{2A-7C} at section 103. These configuration variables then determine when a change is made from one sound effect to another over the span of a given speed step resolution. These change divisions are termed break points and are set based upon 128 speed step resolutions in section 543 of FIG. 14. The software then branches to section 544 of FIG. 14 to FIG. 19 at section 578. Further detail is offered later on FIG. 19.

Moving back to FIG. 11 at section ⁵¹¹ 510, if the received data does not contain advanced operations information, it is tested to see if it is a baseline packet. If it is, the software branches at section 518

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within the received data is compared to the pre-programmed address of the present invention. If the addresses do not match, it would be known that the information was intended for some other device. The software then branches at section 563 back to FIG. 11 at section 514 to begin receiving a new preamble. If the addresses match, it is known that the information contained within the function Group #1 is intended for this device. The function Group #1 F0-F4 data is extracted in section 564. The data is then tested in section 565 to see if function #1 ^{should be} ~~is~~ on or if it should be off. If function #1 should be on, it is turned on in section 567. If function #1 ^{off} ~~should be~~ off, it is turned ~~on~~ in section 566. Referring now to FIG. ⁷ ~~16~~ ¹⁰, when function #1 should be on, output line #10 on the micro-controller section 101 is brought to a digital "1" state. Output line #10 is connected to the gate of MOSFET transistor Q1 in section 106. If an external device is connected across pins 3 and 4 of J6, current flows through the external device, current limiting resistor R1, and MOSFET transistor Q1; hence, the device is on. When function #1 should be off, output line #10 on the micro-controller section 101 is brought to a digital "0" state. Current ceases flowing through the external device, current limiting resistor R1, and MOSFET transistor Q1; hence, the device is off. Q1, R1, and J6 are in section 106.

Referring back to FIG. 17, the next aspect of software deals with function #0. Function #0 is typically used to control a model train locomotive headlight. A configuration variable is checked to see if baseline operation is in effect in section 568. If it is, the previously extracted baseline head lamp data at 557 is

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used at section 569 to determine at section 570 if function #0 should be On at section 571 or ^{off}~~Off~~ at section 572. Referring now to FIG. ⁷~~16~~, when function #0 should be on output line #9 on the micro-controller section 101 is brought to a digital "1" state. Output line #9 is connected to the gate of MOSFET transistor Q2 in section 106. If an external device is connected across pins 1 and 2 of J6, current flows through the external device, current limiting resistor R2, and MOSFET transistor Q2; hence, the device is on. When function #0 should be off, output line #9 on the micro-controller section 101 is brought to a digital "0" state. Current ceases flowing through the external device, current limiting resistor R2, and MOSFET transistor Q2; hence, the device is off. Q2, R2, and J6 are in section 106. Referring back to FIG. 17, after the state of function #0 is set in sections 568-576, the software then branches at section 577 to FIG. 19 at section 578.

Referring now to FIG. 19. at this point all of the data required to select a model train locomotive sound effect should have been received and processed. In section 579, an appropriate engine sound or other sound effect is loaded based upon the previously set breakpoints and received speed. In the case of a model train diesel locomotive, it is appropriate to imply that if a slow speed has been received, then an engine sound effect of a diesel generator at slow rpm's is selected. Conversely, if a fast speed has been received, an engine sound effect of a diesel generator at high rpm's is selected. If the present invention is used with a model train steam locomotive, varying speed discrete chuff sound effects are selected. If a model train diesel locomotive is stopped, an ultra-low RPM idle sound effect

is selected. If a model train steam locomotive is stopped, a gentle hissing sound is selected. If, at this point, all of the data required to select a model train locomotive sound effect has not been received and processed, a default sound effect is selected. In the case of a model train diesel locomotive, an air release sound effect is selected. In the case of a model train steam locomotive, a steam release sound effect is selected.

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10 Once an engine speed sound effect has been selected, it is compared with the previously selected engine speed sound effect section 580. If the most recently selected sound effect is a higher and faster sound effect, a transitional acceleration sound effect is selected first
15 at section 581. The status of function #4 mute, from the previously received function group #1 is now checked at
a 582. If function #4 ~~mute~~ is active, the selected engine speed or acceleration sound effect is loaded at 583. If function #4 mute is inactive, the software continues
20 without loading an engine speed or acceleration sound effect. Whether or not a speed or acceleration sound effect is loaded, the software continues forward to see if higher priority sound effects should be played. Next, function #3 from function group #1 is now checked at
25 section 584. If function #3 is active, the bell sound effect is loaded at section 585. If function #3 is inactive, the software will continue without loading the bell sound effect. Next, function #2 from function group #1 is now checked at section 586. If function #2 is
30 active, a further test is conducted to see if this is the first time function #2 has been found to be active at section 587. If this is the first time function #2 is found to be active, the first horn or whistle sound

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entry point for an interrupt routine 596. As the word interrupt implies, there is not a particular branch to this routine. Whenever a sound effect nears the end of playback, a signal is generated. This signal triggers an interrupt and causes an immediate branch to this routine. This signal is then monitored at section 597 until the sound effect has completed playback. Once completed, the sound effect is checked to see if it should be repeated or looped at section 598. If it should be looped, the sound effect is replayed at section 599. Once the sound effect is replayed or allowed to lapse, the software then returns to the point of the original branch at section 600.

Referring now to FIG. 11 at section 513, numerous configuration variables are contained within the present invention. ^{Configuration} ~~These configuration~~ variables are pre-programmed by the manufacturer with values which would be acceptable to many end users. However, some model train enthusiasts may desire to alter some or all of these configuration variables to enhance operation based upon unique installations. Section 513 checks to see if a received data packet is intended to alter configuration variables. If it is, a branch at section 520 is taken to FIG. 15 at section 545. In section 546, the configuration variable address is extracted. In section 547, the configuration variable data is written. In section 548, an acknowledgment is issued. An acknowledgment may consist of a motor lurch, a light flash or both. The acknowledgment gives the end user an indication that the programming has been accomplished. The software branches at section 549 back to FIG. 11 at section 514 to begin receiving a new preamble.

It should be understood that various changes and

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5 modifications to the presently preferred embodiments described herein will be apparent to those skilled in the art. Such changes and modifications may be made without departing from the spirit and scope of the present invention and without diminishing its attendant advantages. It is, therefore, intended that such changes and modifications be covered by the appended claims.

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